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135354
13 p

NASA TECHNICAL TRANSLATION NASA TT- 20233

METHOD FOR DETERMINATION OF THE WIND VELOCITY AND DIRECTION

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Translation of "Saett Att Bestaemma Vindhastighet Och Vindriktning", Swedish Patent No. SE 8201738-0

(NASA-TT-20233) METHOD FOR DETERMINATION OF THE WIND VELOCITY AND DIRECTION (NASA) 13 p CSCL 04B N88-20769
Unclas G5/47 0135354

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D.C. 20546 MARCH 1988

NASA

Report Documentation Page

1 Report No	2 Government Accession No	3 Recipient's Catalog No
NASA TT-20233		

4 Title and Subtitle	5 Report Date
METHOD FOR DETERMINATION OF THE WIND VELOCITY AND DIRECTION	MARCH 1988
	6 Performing Organization Code

7 Author(s)	8 Performing Organization Report No
GOESTA JOHAN DAHLIN	
	10 Work Unit No

9 Performing Organization Name and Address	11 Contract or Grant No
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, DC 20546	NASW-4207
	13 Type of Report and Period Covered
12 Sponsoring Agency Name and Address	translation
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, DC 20546	14 Sponsoring Agency Code

15 Supplementary Notes

Transl. from SWEDISH into ENGLISH of "Saett att bestaemma vindhastighet och vindriktning," Swedish Patent no SE 8201788-0. Transl. by SCITRAN, Santa Barbara, CA 93150.

16 Abstract

Accurate determination of the position of an artillery piece, for example, using sound measurement systems through measurement of the muzzle noise requires access to wind data that is representative of the portion of the air from where the sound wave is propagated up to the microphone base of the system. The invention provides a system for determining such representative wind data.

17 Key Words (Suggested by Author(s))	18 Distribution Statement
	unclassified-unlimited

19 Security Classif. (of this report)	20 Security Classif. (of this page)	21 No. of pages	22 Price
unclassified	unclassified	13	

NASA FORM 1626 OCT 86

SWEDEN
(19) SE

(12) Publication Notification [B] (21) 8201788-0 TT 20233
(51) International Class 3 G 01 P 5/02
(44) Application Presented and Notification Published 83-11-21 (11) Publication Number 430 543
(41) Application Generally Available 83-09-23
(22) Patent Application Received 82-03-22 Application Reeived as:
(24) Running Dav x - Swedish Patent Application
(62) Original Application Number - Submitted international patent application with number
(86) International Submission Date - Converted to European Patent Application with Number
(86) Submission Date for Request for European Patent
(30) Priority Data

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(54) Subject: Method for Determination of the Wind Velocity and Wind Direction

(43) PATENT REPORTED
March 1, 1984

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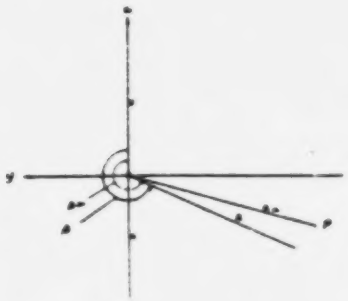
(57) Summary:

Accurate determination of the position of an artillerv piece, for example, using sound measurement svstems through measurement of the muzzle noise requires access to wind data that is representative of the portion of the air from where the sound wave is propagated up to the microphone base of the svstem.

The invention provides a svstem for determining such representative wind data. Using sound measurement systems a noise generated in a suitably, known position is measured as an unknown target. The velocity of the wind w and the angle of bearing α are determined through an iterative computation process. An angle of direction β to the target and a target distance R are computed for varying values of α and w within estimated selected intervals that decrease for each repetition until the values computed for β and R for a value pair for α and w

nearly agree with the actual, known values for the angle of direction and the target distance. The computation process is carried out in calculators/computers and is systematized for saving of computer time.



(56) Cited Publications
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US 4 286 462 (73-189)
US 3 889 533 (73-189)
US 4 206 639 (73-189)

/1*

With the use of sound measurement systems for the determining of the position for generated sound occurrences, for example, muzzle noises from firing artillery pieces or burst or explosive noises, it is necessary to have access to representative data for the strength of the wind and the direction of the wind. As a rule the data mentioned can be obtained from wind indication and measurement with weather radar, but situations often arise where the weather radar measures wind data in another portion of the air than the portion from where the sound wave is propagated to reach the microphones of the sound measurement system. It can then occur that the wind data indicated by the weather radar does not correspond with the wind data in the sound wave transmission routes to the microphones.

In other situations there is no access to weather radar whereby it becomes necessary to use wind data obtained from estimates. In both cases the accuracy is inadequate.

This invention provides a method for determining wind strength and wind direction which makes it possible to receive representative wind data from the actual transmission routes of the sound waves. The determination is made in this invention by means of sound measurement and is applicable with the help of microphones that are grouped for the actual position determination.

The invention is primarily distinguished by the characteristics indicated in the patent application's 1st part.

*Numbers in margin indicate foreign pagination.

In carrying out the procedure according to the invention, a noise is generated in a suitably located position with coordinates that are already known in a coordinate system inserted in the terrain, and this position is measured as the target location in the usual manner with the position determination made through the use of a microphone base by determining the arrival times of the sound waves at the microphones and inputting this into computers/calculators. This is programmed with an analysis algorithm for computing the position of the target in which the algorithm takes into consideration the effect which the prevailing temperature and wind conditions, that is speed and direction, have on the movement speed of the sound wave to the microphones used. The algorithm depends on the method which is used for determining the position. /2
The hyperbola method is the method normally used, according to which the target position is computed as a point of intersection between two hyperbolae, which is determined using the registered arrival times at the microphones and its position coordinates.

To illustrate the invention, it is described with reference to a figure in the attached drawing. The figure shows a microphone base consisting of three microphones grouped in a straight line, which is common with the hyperbola method that requires at least three microphones. The invention, however, is in no way limited to the use of the hyperbola method, but this is only chosen as an example.

As indicated by the figure a coordinate system is inserted with the x-axis along the three microphones and the originating coordinates at the middle microphone. A noise is generated at the known point P. The known, actual radial distance from the original coordinate to this point is designated by R_a, and the known, actual angle of direction to the point P in relation to the x-axis is designated by β_a.

According to the invention, the velocity of the wind w and direction, which is indicated by a bearing angle α, are determined through an iterative computer process in calculators/computers whereby the point P's position, indicated by the radial distance R and the angle of direction β, is computed with regard to the effect of the wind. This position computation is repeated a number of times with varying, assumed values for the velocity w of the wind and the bearing angle α. To reduce the requirement for computer time for this, estimates of intervals are made in which the velocity of the wind w and the bearing angle of the wind should be able to be repeated. Through estimating the interval for α, the ambiguity is avoided if the interval is at least 180°.

Since the wind strength and the wind direction affect the accuracy with which the target location can be determined, different values are obtained for R and β in the repeated computations. The values which are closest to the known values, actual values R_a and β_a are sought and comparable values are selected for the values for w and α as approximate values, around which new, smaller intervals are established for a new round of computations of the target position with fewer variations of the values for w and α . Additional computation rounds are carried out if they are required, with smaller intervals and variations of w and α around new approximate values for these, until the computed values for R and β with acceptable deviations agree for such a pair with the actual values R_a and β_a. Comparable values for w and α are then acceptable as representative values in the actual sound measurement range. /3

To further reduce the time for the searchfor these acceptable values for w and α, the iterative process is systematized, which can occur in various ways. A systematized method with examples of execution is given below which is presently considered to be advantageous and which produces the accepted result most rapidly.

As a time saving feature of this method,the wind velocity w is computed in a somewhat different way than described above. Instead of selecting the value that gives the actual target distance R_a that is closest to the value for R in each computation round as the best approximate value for w, an approximate value for w is computed through linear regression on the computed value pair for the wind velocity w and the target distance R with the insertion of the actual target distance R_a.

According to the systematized method the iterative computation process is divided into the following parts:

1. An arbitrary value for w which is within the estimated interval is selected.

2. With w selected α is varied in suitable stages over the entire interval. For each value of α the value of β is computed, see the figure in the illustration.

3. For a certain value of α the absolute amount of the difference $\beta - \beta_a$ is minimal (β_a equals actual angle of direction toward the target). Normally there is only one such value. It is chosen. If two values occur,one of these is arbitrarily selected.

4. With α selected,w is varies in suitable stages within its interval. For each value for w, R is computed, see the figure.

5. Through linear regression the value of w is computed, then $R = R_a$, where R_a = actual target distance.

6. A smaller interval is placed around the value of α selected according to paragraph 3. Within this interval the process is repeated according to paragraphs 2 and 3 with the value for w computed according to paragraph 5. /4

7. The procedure is repeated according to paragraphs 4 and 5.

8. The iterative procedure is repeated as outlined above until the absolute amount for $\beta - \beta_a$ and $R - R_a$ is below the suitable the threshold value.

Example of Execution

With the microphone grouping according to the figure w and α are determined when a noise is generated at point P with the polar coordinates:

R_a = 9768 m

β_a = 255,70 degrees

Through estimation it is determined that;

$0 \leq \alpha \leq 180$ degrees

$2 \leq w \leq 14$ m/s

The interval for α is divided into stages by 10 degrees. As a value for w 8 m/s is selected - in the middle of the interval. For all α and with the help of the sound arrival times at the microphones, β is evaluated. The result is shown in Table 1, page 6. It appears that the best values pairs are achieved:

α = 120 degrees

β = 255,74 degrees

The value α = 120 degrees is selected and the wind strength is varied in degrees by 2 m/s. The radial distance R is computed with the evaluation algorithm of the measurement system. The results are shown in table 2, page 6.

Through linear regression of the values in table 2 the coorelation coefficient, r, is determined and the equation:

$$w = mR + w_o$$

where m and w_o = constants

Thus the following is obtained: /5

r = 0.996

w_o = 342,7765 814

m = 0,0356159 681

When r is nearly equal to 1, the regression is reliable. With $r = R_a$ = 9768 m w = 5,12 m/s is obtained.

A new interval is now chosen for α :

$100 \leq \alpha \leq 140$ degrees.

The interval is divided into stages by 5 degrees. The wind strength is selected at 5.12 m/s. For all values of α, β is evaluated. The result is shown in table 3, page 6. As teh best value pairs the following are obtained:

α = 110 degrees

β = 225, 71 degrees

The value α = 110 degrees is selected. The wind strength w is varied in degrees by 0.1 m/s within the interval:

$4{,}92 \leq w \leq 5{,}32$ m/s

Table 4, page 6 shows how R varies with w.

Linear regression of values in table 4 yield:

r = 0,9975

w_o = -317,7769 826

m = 0,0330441558

With R = 9768 m, w = 5,00 m/s is obtained.

Finally with w = 5,00 m/s and α = 110 degrees, comparable values are finally computed for β and R.

This results in:

β = 255,70 degrees

R = 9768 m

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1 Tabell 1

5 α grader	6 w m/s	β grader
0		256,19
10		256,36
20		256,50
30		256,60
40		256,65
50		256,67
60		256,63
70		256,56
80		256,45
90		256,31
100		256,14
110		255,95
120		255,74
130		255,52
140		255,29
150		255,06
160		illegible
170		254,62
180		254,43

2 Tabell 2

5 α grader	6 w m/s	R m
120	2	9678
	4	9737
	6	9795
	8	9849
	10	9904
	12	9967
	14	10012

3 Tabell 3

5 α grader	6 w m/s	β grader
100	5,12	255,83
105		255,77
110		255,71
115		255,64
120		255,57
125		255,51
130		255,43
135		255,36
140		255,28

4 Tabell 4

5 α grader	6 w m/s	R_m
110	4,92	9765,66
	5,02	9768,59
	5,12	9771,52
	5,22	9775,26
	5,32	9777,38

Key:

1 - Table 1

2 - Table 2

3 - Table 3

4 - Table 4

5 - Degrees

6 - meters/second

Patent Application

1. A method for determining the wind velocity and wind direction is proposed, that usesthe effect of the wind on the travelling times of sound pulses generated by a sound source in various directions from the source or the sound to a number of microphones. They are grouped at intervals and at various directions to the sound source for the receiving of such sound pulses, characterized by the fact that the microphones are placed to form a microphone base grouped according to the method selected for position determination of sound source by means of sound measurement and sound sources with a positioning with regard to distance and direction from the microphone base for such a determination of its position, all with fixed positions in a coordinate system placed in the actual range, so that a sound incidence, for example, a sound noise generated by the sound source and its arrival time at the respective microphones is registered to be used for the determination according to the selected method of sound source coordinates (α,R) through a computation, that includes corrections for the specified effects of wind, and so that an iterative computation process is carried out.Thisinvolvesrepeated series of such coordinate determinations with wind corrections for a number of different pair-combinations of varying values for wind velocity (w) and a wind direction indicating angle (α) within the selected estimated intervals for it. The intervals for each new series are selected continually lower around the best estimated values obtained in the preceding series for the specified wind angle (α) and the wind speed (w) until the best pair of combinations yield the computed coordinates in a series, a direction angle (β) to the respective angle, a distance (R) to the sound source, which agrees with the known, actual values for this with an acceptable tolerance.

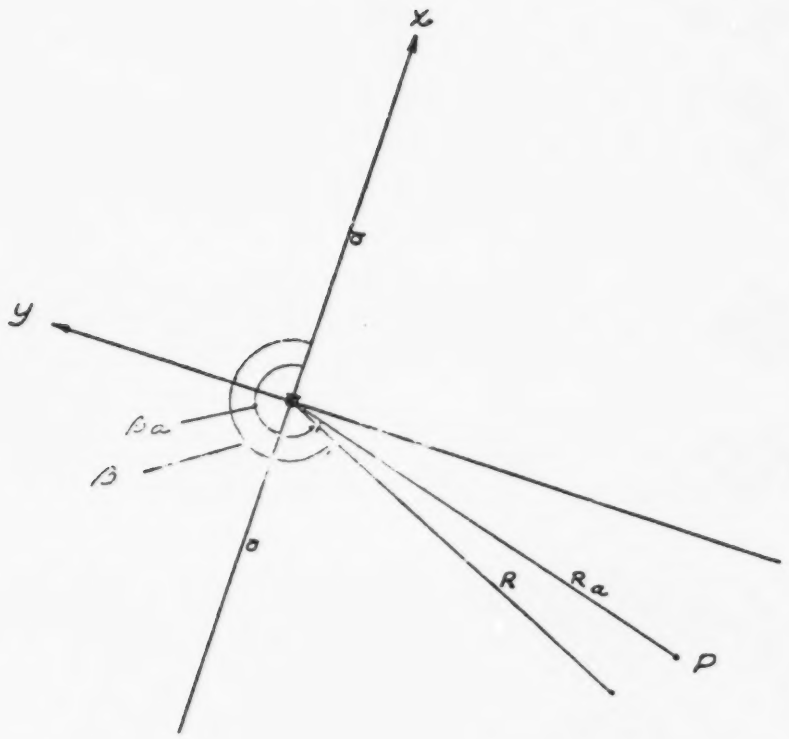
2. A method according to patent application 1, characterized by the fact that the computation process is carried out so that the two values for the wind bearing angle (α) and the wind velocity (w) are alternately varied with selected degrees for the specified fixed value for the other quantity within its respective interval.

3. A method according to patent application 2, characterized by the fact that in each computation series the angle of direction (β) is computed for varying values for the bearing angle of the wind (α) to determine the best approximate value for this, and the target distance (R) is computed with this value for the bearing angle (α) for the wind velocity (w) to determine the best approximate value for this.

4. A method according to patent application 3 characterized by the fact that the value within the interval which yields the least difference between the computed and actual angle of direction (β respectively β_a) is selected as the best approximate value for the bearing angle (α). /8

5. A method according to patent application 3, characterized by the fact tnat the best approximate value for the wind velocity (w) is obtained through linear regression of the computed value pairs for the wind velocity (w) and the target distance (R), whereby it is computed with the actual target distance (R_a).

6. A method according to some of the preceding patent applications, characterized by the fact that the determination of the wind data is carried out with a computer/calculator programmed with the iterative computation process and the registered arrival times at the microphones fed into it.


x
y
a
βa
β
o
R
Ra
P

Summary

Precise determining of the position of an artillery piece, for example, using sound measurement systems through the measurement of the muzzle noise requires access to wind data which is representative of that portion of the airspace from where the sound wave is generated up to the microphone base of the system.

The invention provides a method for determining such representative wind data. Through the use of sound measurement systems, a sound generated in a suitably, known position is measured as an unknown target. The velocity of the wind w and the bearing angle of the wind α are determined through an iterative computation process. A direction angle β to the target and a target distance R are computed for varying values of α and w within the specified estimated intervals which are decreased for each repetition until the values for β and R computed for a value pair for α and w almost agree with the actual, known values for the direction angle and the target distance. The computation process is carried out in calculators/computers and is systematized to save computer time.